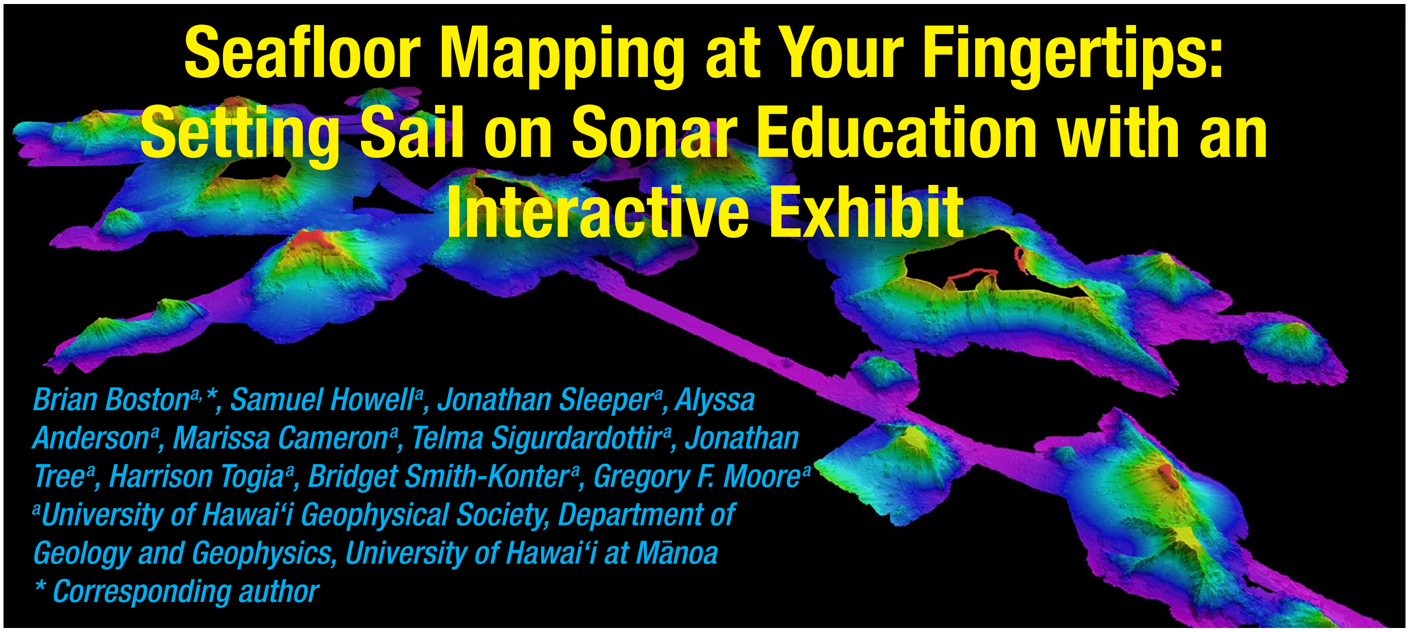

Seafloor Mapping at Your Fingertips: Setting Sail on Sonar Education with an Interactive Exhibit

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Abstract

We present an activity focusing on an interactive sonar display for educational outreach promoting education of both marine geology and basic geophysical concepts. Students act as chief scientists for a scaled-down sonar research cruise by creating cruise tracklines, collecting data, and visualizing and interpreting the results. The exhibit uses computer-controlled motors, an ultrasonic transducer, and a real-time updating bathymetry plot to move the toy-sized boat, collect data, and visualize the data in three-dimensions. Using current technology to scale down large research experiments, such as sonar cruises, allows students to experience and learn about more aspects of research science firsthand.

Introduction

With ~90% of the ocean floor remaining unexplored by detailed mapping cruises (Becker et al., 2009) and remote regions having sparse coverage (Wessel and Chandler, 2011), ocean exploration will continue to provide valuable new information about earth systems. Bathymetric mapping with sonar is a conventional technique that uses sound to measure the seafloor depth, providing essential data for understanding oceanography, marine biology, and marine geology. Education about the technique and scientific results of seafloor mapping is vital to public understanding of the impact of large research cruises on scientific discoveries.

To further educate students and the public of Hawai'i about sonar research cruises a novel interactive sonar display was designed, built, and presented, aimed to help students 'visually' understand basic geophysical principles by mimicking a scientific hull-mounted echo-sounder research cruise like Research Vessel (R/V) *Kilo Moana* operated by the University of Hawai'i. This seafloor mapping model, project Sonar Education and Exploration (SEE), demonstrates how sonar is used to explore marine geology, including the Hawaiian Islands, by utilizing the actual techniques employed by scientists. To do this, we placed an active sonar sensor beneath the toy-sized R/V *UHGS* (University

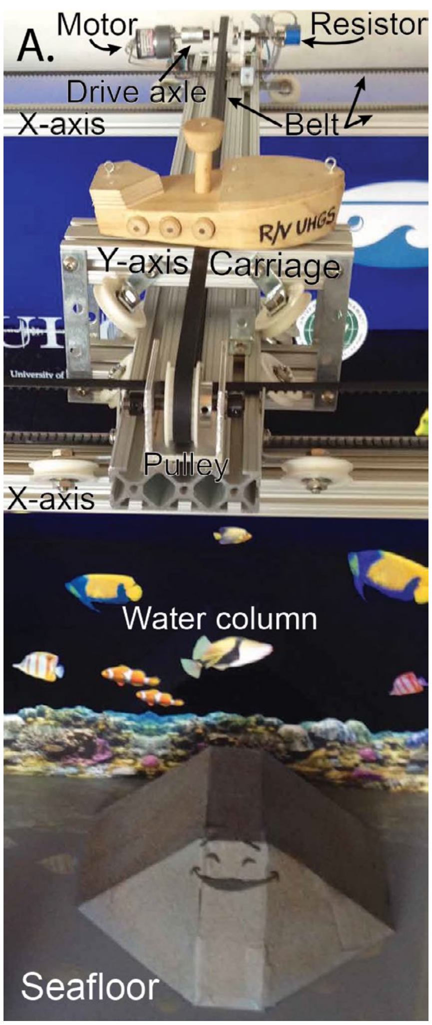
Figure 1. A. R/V *Falkor* (82.9 m length overall) before a scientific seafloor mapping cruise. B. The setup of project SEE that mimics a seafloor mapping cruise. The navigation for each cruise is inputted on the touchscreen monitor. This input is translated into the survey area and the sonar cruise starts collecting data and outputting the results in real time on the bathymetry display.

of Hawai'i Geophysical Society), which was driven by computer-controlled motors. Project SEE demonstrates the practical use of concepts such as wave physics and simple geometric calculations. The demonstration provides an avenue for students of all ages to learn about the use of echolocation in many settings, from its use by animals, such as bats and marine mammals, to scientists' use of sonar equipment to map the seafloor with research vessels. With recent mapping cruises to the Northwestern Hawaiian Islands (e.g., Kelley et al., 2015) using R/V *Falkor* (Figure 1A), our project demonstrates the basic concepts and physics behind the techniques used onboard a real research vessel to discover the nearby marine geology to local students on O'ahu. In this paper, we discuss a new technique for sonar education by using a scaled interactive version of a research cruise.

Public Demonstration

We publicly presented project SEE at the University of Hawai'i at Mānoa School of Ocean and Earth Science and Technology's (SOEST) Biennial Open House on October 23-24, 2015. An estimated 6,000 people visited this event, of which approximately 4,000 were students from 50 local elementary, middle and high schools. We coordinated our display to be in front of the SOEST 'video wall', where we co-led a tour and a three-dimensional (3D) fly-through of Hawaiian Islands bathymetry, highlighting recently collected bathymetry data from the Northwestern Hawaiian Islands (similar fly-throughs can now be run using the same dataset with programs like Google Earth). These two exhibits allowed visitors to see a simple demonstration of the basic geophysical principles of sonar mapping acquisition alongside new bathymetric maps that were created using those principles and similar technology.

Figure 2. R/V *UHGS* conducting a sonar survey. A. The setup of the y-axis.



Project Design and Construction

Two sonar systems were built: a pilot low cost version and a more advanced system, project SEE. The pilot version used a wooden frame, rope and pulleys to propel the boat, a transducer, and our mapping and visualization software (Boston et al., 2014). From this experience, we redesigned the system for project SEE to improve ship propulsion and tracking, mapping resolution, and interactive capabilities.

We designed project SEE to be interactive and easily reusable. The frame consisted of t-slotted aluminum (Figure 1B), which is strong, reusable, and customizable. A transparent blue piece of Plexiglas provided extra support for the x-direction and created the illusion of an undersea environment. A gray piece of Plexiglas formed a flat base at the bottom of the frame (the 'seafloor'), with the color chosen to mimic marine snow.

On top of the frame sits the XY table, also constructed from t-slotted aluminum, which allowed for navigation and movement over the survey area. The x-axis consisted of two aluminum pieces that are directly mounted to the frame. We put the y-axis frame piece on wheels to allow motion in the x-direction, and connected it to the x-axis timing belts on both ends. We created a y-axis carriage from leftover t-slotted aluminum, using eight wheels to allow motion along the y-axis, and connected it to the y-axis timing belt (Figure 2).

Electric DC motors were used to drive the timing belts in both the x and y directions. The motors were wired to separate motor controllers, which allows for easier control and performance of an electric motor. USB connectivity from the motor controllers allowed for direct motor control from a computer. Potentiometers, a type of resistor, were connected to each drive axle in order to measure the number of turns, which can be calibrated and translated into distance, forming our navigation system for both x and y directions.

For wiring the system, we used altered retractable USB cables and speaker wire. This allowed for use of the USB wires in a modified set-up to help with cable management, so that the cables would not dangle around as the boat moved. We used three USB cables along the x-axis, and one at the y-axis to connect to the carriage sensor. The x-axis cables did cause moderate drag in the x-direction, but only when the cables were fully extended. Otherwise, this wiring system worked well and kept the cables from hanging in the way of the survey and largely out of sight.

We attached a toy ship to the top of the y-axis carriage (Figure 2) for a visual representation of R/V *UHGS* and placed a transducer beneath the y-axis carriage for the sonar sensor. The transducer produces a sound wave and measures the time for a sound wave that has been transmitted to and reflected back from objects. Based on the time length and the speed of sound in air, we can measure the distance to the object. This is the exact same technique used to map the seafloor, and we thought mimicking this technique was important for the students to understand, rather than using more accurate air-based techniques. We used a 42-kHz ultrasonic sensor with a factory rated resolution of 1 mm, an accuracy of 1% for most uses. The sensor has a narrow beam width, and can detect objects from 30 cm to 5 m, within our designed frame height. The sensor included a USB interface, facilitating communication with a computer through a COM port. The sensor was small and light, allowing for easy mounting beneath the y-axis carriage. We wrapped the sensor in paper (similar to a microphone pop filter), which we found helped to reduce noise from the Plexiglas side of the frame.

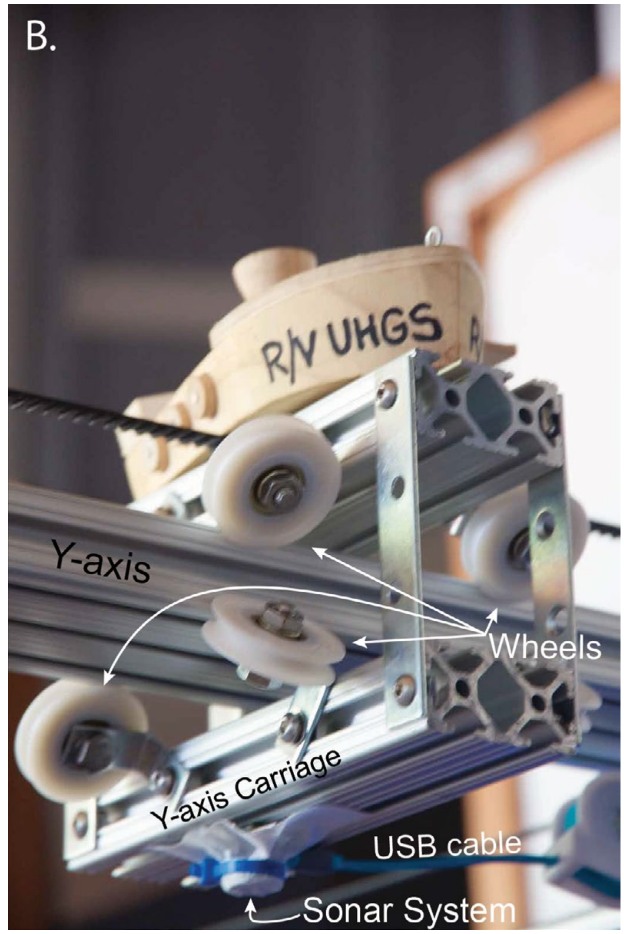


Figure 2. R/V *UHGS* conducting a sonar survey. B. The setup of the y-axis carriage.

The sensor was favorable because industry tests showed a narrow beam width for a range of object acoustic hardness. The target's acoustic properties play a large role in how much sound is transmitted through, absorbed, diffused, or reflected by the target. The higher the acoustic hardness, the more sound is reflected and can be detected by the sensor easier and to greater distances, whereas acoustically soft objects tend to absorb more sound than reflecting it. We tested the sensor against different materials, including modeling clay and cardboard, to see how the hardness of the target affected the imaging ability of the sensor. We found that cardboard was a sufficient reflector of the sound wave at our estimated target distances even though cardboard is acoustically softer than many other materials. We also tested how well the sensor could pick up steep angles, and found it did an acceptable job on high angles and that modifications to objects were not necessary for the sensor. The Plexiglas seafloor was an acoustically hard material, allowing for a consistent background reading.

Interactive Operation

We operated our sonar ship and displayed the data using MATLAB, a numerical computing environment. We developed custom computational code for communication with the motors and motor controllers, potentiometers, sonar sensor, and user input, all within the same coding environment. We designed and created a touch-enabled graphical user interface (GUI) that allowed for custom survey design, real-time updated ship-tracking, and that displayed bathymetry in a friendly computer environment for the public audience. Users could use the GUI to select a pre-designed, random survey, or design their own by selecting waypoints (Figure 3A). The data was output to a 3D display

The MATLAB code used to run project SEE is available at https://github.com/UHGS/Project_SEE

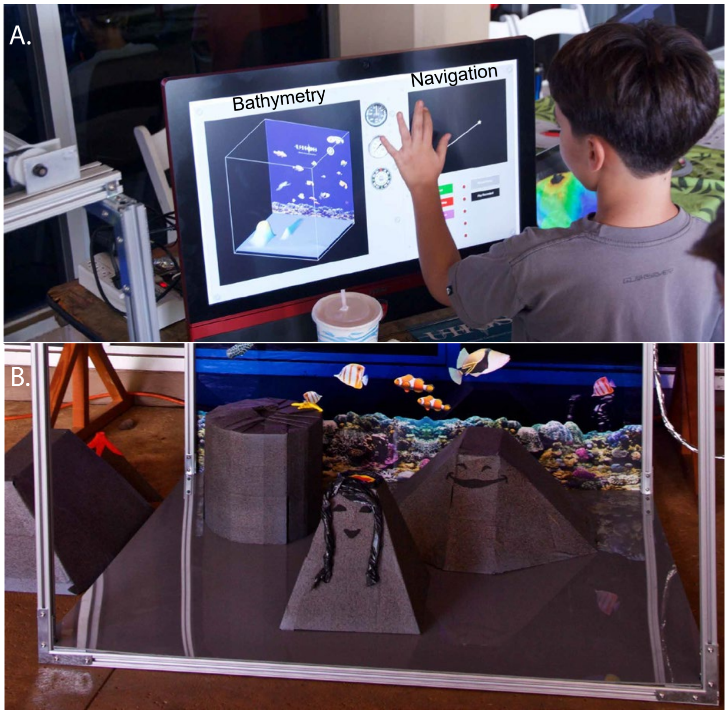


Figure 3. A. A student chief scientist creates a survey by picking waypoints on the touchscreen. B. Seafloor features to be imaged by R/V *UHGS*.

using a surface grid that was updated in real-time. The output display featured a picture of the frame and decorated blue Plexiglas background to help visualize the 3D objects in context, and the data output allowed for touch-enabled 3D rotation and zoom of the display to further visualize the results.

The interactive component consisted of two parts. 1) We made volcanic seamounts and a guyot out of cardboard, applied textured spray paint, and decorated them with modeling clay for our final seafloor features on top of the gray "seafloor" Plexiglas (Figure 3B). We allowed the users to move or choose what seafloor objects to image. 2) We used a touchscreen computer to allow the users to create their own customized survey design and rotate the displayed image (Figure 3A). Users would pick waypoints, and then we would run their 'cruise' based on their survey design. This allowed us to further discuss the role of planning a survey and why much of the ocean is still not mapped. These interactive components allowed for greater interest and more questions about what was happening during the survey. Finally, co-locating this sonar booth with a Hawaiian bathymetry display allowed participants to connect our simple sonar demonstration with real maps of the seafloor to understand how this technology is utilized by geoscientists (Figure 4).

Figure 4. Students conduct a sonar cruise and listen to an explanation of how the system works with recently collected bathymetry from the Northwestern Hawaiian Islands being discussed in the background.

Summary

Project SEE allowed students to run a scaled-down sonar cruise, providing an interesting and stimulating experience to help attract future geoscientists. With the recent development of low cost 3D printing and computer numerical control milling machines, we were able to integrate a wide variety of design options and off-the-shelf parts to implement our vision. Project SEE has continued to run during the SOEST Biennial Open House benefiting from the reusable design. Future projects can use similar methods to provide scaled interactive models demonstrating geophysical principles and methods, and help stimulate interest in the geosciences.

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